Generation of Laser-accelerated Electron beams at KAERI for Nuclear applications

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1. Introduction

The interaction of a high intensity laser pulse with gas jet or thin foil target, i.e., laser-plasma interaction, can produce extremely high accelerating gradient of electric field, resulting in the generation of highly energetic electrons in such a short distance. Physical processes [1], such as, the Brunel effect [2], ponderomotive or **j**×**B** acceleration [3,4], and wakefield acceleration [5], are contributed in this acceleration.

In underdensed plasma, it is possible to generate relativistic plasma waves through direct interactions with the main laser pulse, leading to generate highly energetic electron beams. Also, in a short-pulse regime, nonlinear relativistic plasma waves can be generated for quasi-monochromatic electron beam, leading to the growth of a wakefield plasma wave [6,7], or formation of a plasma bubble due to self-focusing and channelling effects [8,9].

If a high-Z solid target is placed behind the interaction area, as like, a gas target, these accelerated electrons will generate high-energy bremsstrahlung radiation [10,11], which can be used for radiography, nuclear activation, photonuclear reaction, radiation effects, radiation safety studies and so on.

For nuclear applications using high intensity lasers, it follows three steps: firstly, the generation of several tens of MeV electrons in laser plasma interaction; secondly, the conversion of generated electrons into MeV photons via Bremsstrahlung process; finally, nuclear reactions or activations by the high-energy photons. The first step depends on the plasma physics related to characteristics of the laser, and the rest relate to characteristics of the generated electrons.

A 30 TW Ti:sapphire laser system has been developed at KAERI for researches on laser particle acceleration and their nuclear applications. Tens of MeV electrons were recently observed with a divergence of ~ 10 mrad and the optimization of the condition for qusai-monochromatic electron generation for bremsstrahlung emission suitable for photonuclear reactions or photofissions are underway.

We presented the experimental results of laser-accelerated electron generation and then investigate the bremsstrahlung radiation for the potential nuclear applications.

2. Experimental Set-up

A 30 TW Ti:sapphire laser system at KAERI has been developed and utilized for particle accelerations via laser-plasma interaction. A total energy of 3.5 J from two Q-swtiched frequency-doubled Nd:YAG lasers is applied to extract total amplified energy of 1.3 J. With compression efficiency of ~ 70%, the final energy at target chamber is 0.9 J with pulse duration of 27 fs, yielding a 30-TW peak power. The temporal contrast is estimated to be 10^{-8} and 10^{-10} in a picoseconds and a nanosecond ranges, respectively. By selecting pumping energy, the laser system can be operated at two different peak powers, 10 TW and 30 TW.

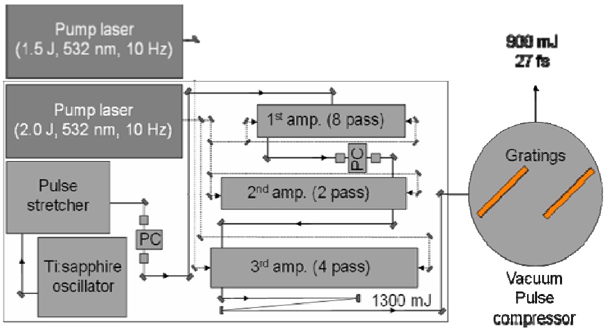

Fig. 1: Schematic of the KAERI 30 TW laser system.

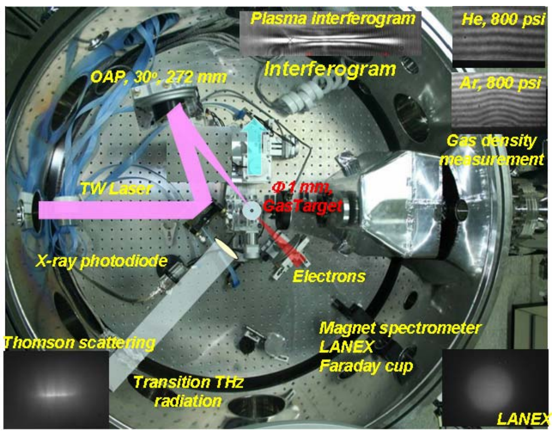

Fig. 2. Experimental set-up for Laser-induced electron generation

To generate quasi-monoenergetic electron beams, the laser beam was focused on a helium gas jet target using off-axis parabola (OAP) mirror with a focal length of

272 mm and a waist of 6 ~ 9 μm depending on beam size of collimated incoming laser beam. The size of supersonic nozzle for gas jet target is 1 mm in diameter. We measured energy spectrum of electrons generated via laser-plasma interaction.

To increase the maximum energy and reduce the energy spread, the long gas nozzle with rectangular shape is installed combined with a spherical focusing mirror of 1 m long focal length and a flat mirror with 9 mm hole. Using 30 TW laser power, it is expected to accelerate electrons up to several hundred MeV.

3. Results

MeV electrons with high energy spot around 25 MeV and 45 MeV, respectively, were observed with a divergence of ~ 10 mrad but, with quite broad energy spread. We need to optimize the plasma condition to reduce the energy spread, or separate the hot spot from the lower energy electrons after the bending magnet. When the intensity at a gas target was kept as ~1.3×10^{19} W/cm^2, accelerated electron beam became more stable and has lower divergence for large laser beam waist and longer Rayleigh range.

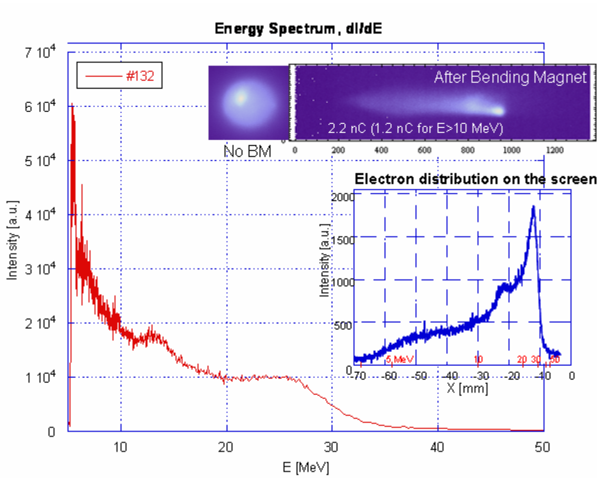

Fig. 3: Energy spectrum of laser accelerated electrons.
Laser : 9.5 TW, 30 fs, 800 nm (ϕ30 mm iris),focal spot of 8.4 μm FWHM, Rayleigh range of Z_R ~ 220 μm
Gas jet : He, ϕ1 mm dia. nozzle, distance from nozzle Δ*l*= 1.3 mm, 650 psi backing pressure, density of ~ 1.6×10^{19} cm^{-3}

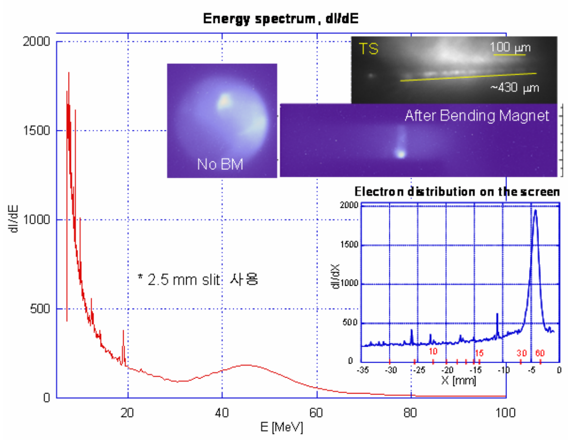

Fig. 4: Energy spectrum of laser accelerated electrons.
Laser : 6.3 TW, 30 fs, 800 nm (ϕ40 mm iris),focal spot of 7.0 μm FWHM, Rayleigh range of Z_R ~ 140 μm
Gas jet : He, ϕ1 mm dia. nozzle, distance from nozzle Δ*l*= 0.95 mm, 650 psi backing pressure, density of ~ 2.3×10^{19} cm^{-3}

4. Summary

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